

Nov. 16, 1943.

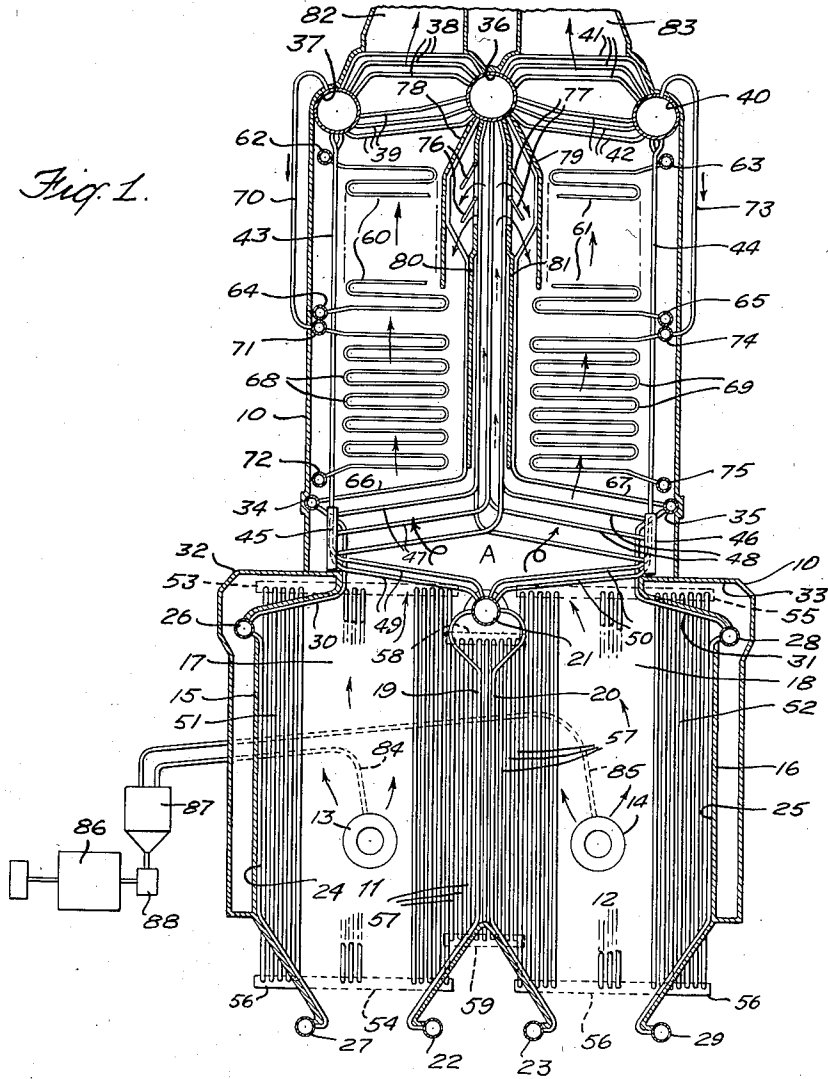
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2,334,187

VAPOR GENERATOR

Filed May 3, 1939

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FULL LINES = FIRING FOR CONSTANT SUPERHEAT TEMPERATURE
DOTTED LINES = EQUAL FIRING OF BOTH FURNACES

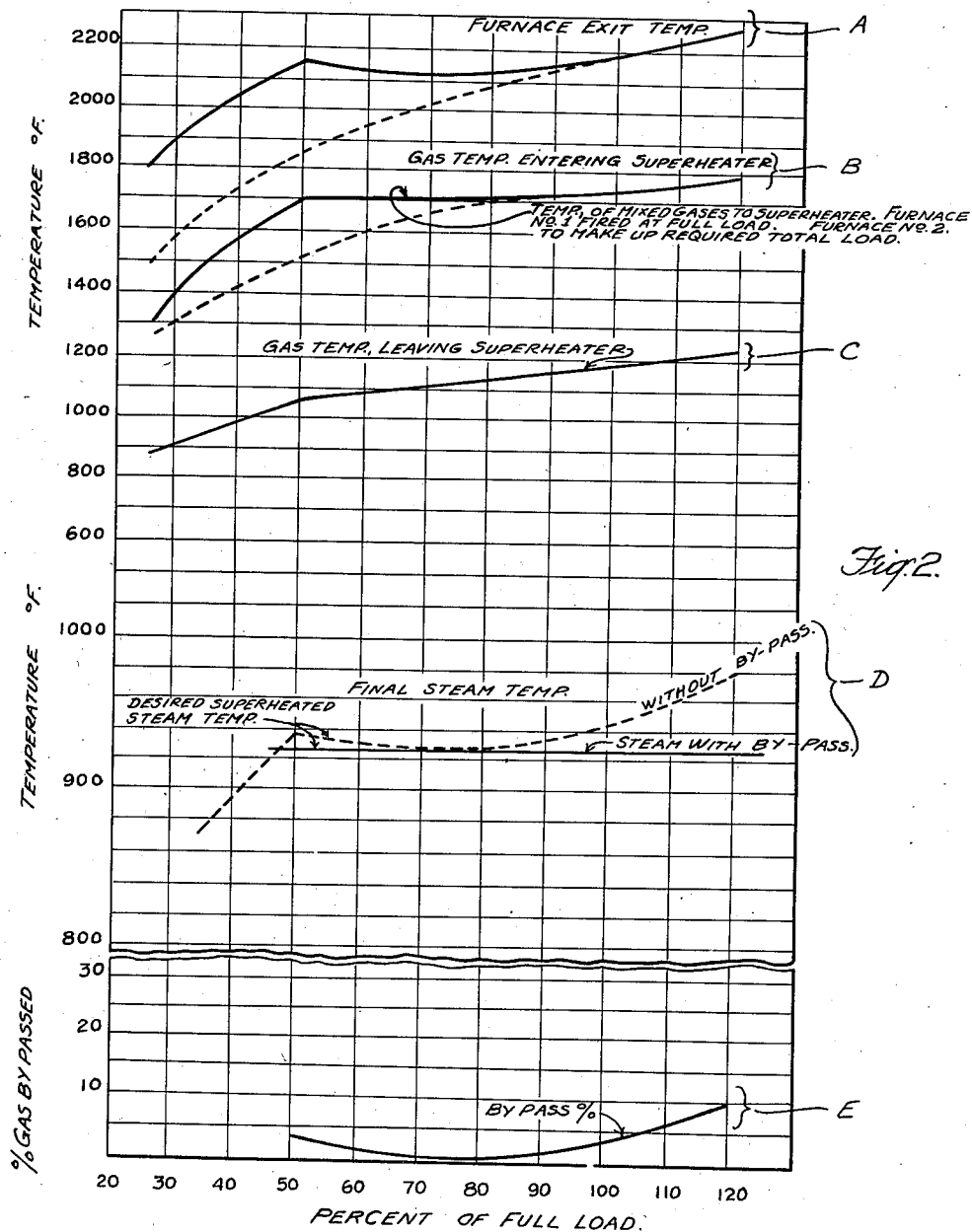


Fig. 2.

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VAPOR GENERATOR

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11 Claims. (Cl. 122—235)

This invention relates to vapor generators, and more particularly pertains to apparatus for the control of superheat over a wide range of loads in steam generators utilizing a plurality of separate furnaces operating in parallel.

The invention is based upon the discovery that when a steam boiler is fired by two or more furnaces operating in parallel, and each furnace is provided with heat absorbing means such as water walls or other wall cooling surfaces, and the boiler heating surface is so arranged with respect to the furnaces that the gases leaving the furnaces mix, even imperfectly, before entering the boiler heating surface, the temperature of the mixed gases is lowest when the furnaces are evenly fired, and increases when the furnaces are unevenly fired. For example, if a steam boiler fired by two furnaces, is operated at half load, and if this load is developed by firing one half of the required fuel in each of the furnaces, the temperature of the gases entering the boiler will be considerably lower than if the load is developed by firing all the fuel required to develop the load in one furnace and none in the other. This follows from the fact that when the required load is developed by firing fuel equally in both furnaces, the cooling surfaces in both furnaces absorb heat from the flame and the gases on their way to the boiler, whereas when all the required fuel is fired in only one of the two furnaces, the cooling surface in the inactive furnace is not effective in cooling any portion of the flame or the gases, and hence less heat will be absorbed from the gases before leaving the furnaces, and therefore the temperature of the gases entering the boiler will be higher. When the boiler is operated at above 50% of load, and it is desired to maintain the maximum possible gas temperature through the boiler, one furnace is fired at its full load, which corresponds to one-half of full boiler load, while the other furnace is fired to make up the difference. With this method of operation, the temperature of the gases entering the boiler from 50% to 100% of load will always be higher than it would be if the equivalent load is developed by firing an equal amount of fuel in each of the two furnaces.

In accordance with the present invention, the application of this principle makes it possible to obtain a comparatively flat temperature curve for the gases entering the superheater section of the boiler, and hence to realize a substantially constant final steam temperature over a wide range of loads hitherto obtainable only by the use of more expensive and cumbersome super-

heating means commonly employed in steam boilers fired by a single furnace.

One such means heretofore used is a superheater having both convection and radiant heat absorbing sections connected in series or in parallel. Another such means includes an oversize convection superheater which normally gives a higher degree of superheat than required at full load and provides the desired steam temperature at some predetermined lower load. A by-pass in parallel with the superheater is utilized so that at loads above the low load for which the superheater is designed, a certain amount of the gases is by-passed around the superheater to keep the superheat down to the desired level. When such an arrangement is employed with single furnace boilers, the superheater is necessarily large in order to provide the desired steam temperature at the predetermined low load because of the rapidity with which the temperature of the gases entering the superheater decreases with decreasing load. Consequently the volume of gases that must be by-passed at high loads, so as to prevent the superheat from exceeding the predetermined desired level, is considerable.

However, when the present invention is utilized and two or more separate furnaces are fired differentially, the desired steam temperature may be obtained at a predetermined low load with considerably less superheating surface due to the fact that the gas temperature entering the superheater changes very little from half to full load. Therefore, in order to control accurately the temperature of the steam above half load, appreciably less by-passing need be done in boilers fired by two or more furnaces than in boilers fired by a single furnace, as a result of which the superheater and by-pass means can be substantially smaller and less expensive.

The characteristics of the invention will be understood from the following description when considered in connection with the accompanying drawings forming a part thereof, and in which:

Fig. 1 is a vertical sectional view illustrating more or less diagrammatically, a steam generator embodying one form of the invention, and

Fig. 2 is a chart showing a group of curves typical of the variations in gas and steam temperature obtained over a wide range of loads, and illustrating graphically the effect on these temperatures of differentially controlled and equal firing of two furnaces in a steam generator embodying the form of the invention shown in Fig. 1.

Like characters of reference refer to the same or to similar parts throughout the several views.

Referring to the drawings, particularly to Fig. 1, reference character 10 designates generally the setting of a steam generator having two adjacently disposed furnaces 11 and 12, which are fired by fuel burners 13 and 14 respectively, and include substantially vertical side walls 15 and 16, rear walls 17 and 18, and front walls not shown. Midway between the side walls 15 and 16 and parallel thereto are two rows of closely spaced vertical water tubes 19 and 20, which are connected at their upper ends to a boiler drum 21, and at their lower ends to headers 22 and 23 respectively. The rows of tubes 19 and 20 extend between and normal to the front and rear furnace walls and thus provide a partition which divides the setting into two separate furnaces which are arranged for parallel operation. Water wall tubes 24 and 25 are disposed on the inner surface of the side walls 15 and 16 respectively, with the tubes 24 being connected at their upper ends to a header 26 and at their lower ends to header 27, and the tubes 25 being similarly connected to upper and lower headers 28 and 29. The lower headers 22, 23, 27 and 29 are connected into the boiler circulation by suitable connections, not shown. Water wall tubes 30 and 31 line the inner surface of the furnace roof portions 32 and 33 respectively, and are connected at their lower ends to the headers 26 and 28 and at their upper ends to headers 34 and 35 respectively. A centrally located steam and water drum 36 is connected with a steam and water drum 37 at one side of the setting by circulators 38 and 39, and is connected with another similarly disposed steam and water drum 40 on the other side of the setting, by circulators 41 and 42. A vertical row of downcomer tubes 43 connects the drum 37 with vertical headers 45, and a similar row of downcomer tubes 44 connects the drum 40 with vertical headers 46. Groups of steam generating tubes 47 and 48, spaced relatively widely apart, connect the headers 45 and 46 respectively, with the central steam and water drum 36. Groups of inclined screen tubes 49 and 50 extend across the path of the gases leaving the furnaces between the drum 21 and the headers 34 and 35 respectively, and have their upper ends connected to drum 37. The inner surfaces of the rear walls 17 and 18 of the furnaces are lined respectively by groups of water wall tubes 51 and 52. The tubes 51 are connected to an upper horizontal header 53 and a lower horizontal header 54, while the tubes 52 are connected to an upper horizontal header 55 and a lower horizontal header 56. A group of short water wall tubes 57 also line portions of the inner surfaces of the rear furnace walls, and these tubes are connected to an upper header 58 and to a lower header 59. It will be understood that the front furnace walls, not shown, may also be provided with similar groups of water wall tubes.

On opposite sides of the upper portion of the setting and beneath the circulator tubes 39 and 42 are economizer sections 60 and 61. Feed water from any suitable source enters the inlet headers 62 and 63 and flows in parallel through each of the economizer sections to outlet headers 64 and 65 respectively, and thence by conduit connections, not shown, to the boiler circulation. Header 34 is connected to the steam and water drum by a row of spaced boiler tubes 66, the lower portions of which are horizontally inclined, and the header 35 is connected to the

drum 36 by a similar row of spaced boiler tubes 67. In the space between economizer section 60 and the lower horizontally inclined portions of the tubes 66 is disposed a superheater section 68, and on the opposite side of the setting is a similarly disposed superheater section 69. Saturated steam from the drum 37 flows through steam line 70 to superheater inlet header 71 of superheater section 68 and thence through that section to the outlet header 72. At the same time, steam line 73 conducts steam from the drum 40 to inlet header 74 of superheater section 69, and after flowing therethrough, the steam flows into outlet header 75. From the superheater outlet headers 72 and 75, the superheated steam is conducted to its point of use by suitable means, not shown.

A by-pass for the gases around the two superheater sections 68 and 69 is provided in the zone through which pass the vertically disposed portions of the tubes 47, 48, 66 and 67. As shown, vertically extending baffles 80 and 81 are disposed on or adjacent the tubes 66 and 67 from the horizontally inclined portions thereof upwardly to the point where these tubes flare outwardly away from the tubes 47 and 48, where these baffles bend inwardly to the outermost tubes 47 and 48 and continue upwardly therealong to the drum 36. One or more openings are provided in each baffle 80 and 81 adjacent their upper ends, which are controlled by dampers 76 and 77 respectively, to regulate the quantity of gases flowing through the by-pass and around the superheater section in one or both of the gas passes. Baffles 78 and 79 are disposed along, or adjacent to, the upper ends of tubes 66 and 67, and extend from the drum 36 downwardly nearly to the bottom of economizers 60 and 61, whereby gas passages are provided through which gases from the by-pass enter the gas passes in the zone of the economizers 60 and 61. Suitable means are provided to operate the dampers 76 and 77, either individually or in groups, to provide the desired degree of regulation of the flow of gases through the by-pass and over each or both sections of the superheater. Thus all the gases pass over the economizer sections and thereafter leave the boiler through the flues 82 and 83.

As shown diagrammatically in the drawings, fuel in the form of pulverized coal is fed to the burners 13 and 14 through fuel lines 84 and 85 from pulverizing mill 86. Variable amounts of fuel may be supplied to each burner, and the relative rates of firing of the two furnaces thereby controlled by means of a fuel proportioning valve 87 directly connected to the discharge of mill exhaustor 88, or, if desired, two separate controlling exhaustors may be used with one mill, or separate mills for each furnace may be employed. Obviously, the furnaces may be fired by other fuels, if desired.

In operation, the gases leaving the two furnaces will mix in the space A before entering the boiler proper. Before entering the superheater sections, the mixed gases pass over the widely spaced boiler tubes 47 and 48, as a result of which the temperature of the gases is reduced to a predetermined value at maximum load above which the temperature should not rise, in order to minimize slagging. At loads below maximum, the temperature of the gases entering the superheater sections, and the final steam temperature, is maintained as nearly constant as possible by differentially firing the two furnaces. Additional superheat control is obtained by causing desired

quantities of the gases to flow through the by-pass. The by-pass control dampers are located near the top of the by-pass flue, which contains enough boiler surface to sufficiently cool the gases passing through the dampers so that damper design problems are minimized, and the use of expensive high temperature metals is minimized also.

The curves in Fig. 2 illustrate graphically the calculated operating data for a steam generator embodying the form of the invention illustrated in Fig. 1. Fig. 2 also shows the effect on gas and steam temperatures, of differentially controlled and equal firing of the two furnaces, as well as the effect of the by-pass on the final steam temperature. The dotted line curves show the effect on performance at all loads of equally firing both furnaces, under which conditions the natural characteristics of the superheater determine the final steam temperatures. The full line curves show the effect on performance when firing the furnaces differentially to obtain the degree of superheat indicated by the two curves D. The upper curve D shows the final steam temperature obtained by differential firing alone, that is, without the use of the by-pass, while the lower curve D shows the final steam temperatures which may be obtained by differential firing and the use of the by-pass in the range between 50% and 120% of full load. Curve E shows the percent of total gas by-passed at the various loads within this range. The curves A show the temperatures of the mixed furnace gases before entering the boiler, and indicate the difference in these temperatures when the furnaces are fired equally, and when they are fired differentially. Curves B show the temperature of the mixed gases entering the superheater sections, and the difference in the temperature of these gases at various loads effected by equal or by differential firing. The curve C shows the gas temperature leaving the superheater sections.

The curves of Fig. 2 show clearly that when the two furnaces are fired equally, the temperature of the gases leaving the furnaces and the temperature of the gases entering the superheater are materially lower than corresponding temperatures of the gases when the furnaces are fired differentially. Differential firing according to Fig. 2, includes the firing of but one furnace for loads up to half load, and for loads between half and full load, the firing of one furnace at an intensity to produce half load, with the firing of the other furnace at the intensity required for the desired load. When the by-pass is not used, the final steam temperature, or the degree of superheat imparted to the steam, will vary but slightly between 50% and 100% of full load, as shown by the upper curve D. Beyond full load the temperature rises. However, by using the by-pass, the final steam temperature at all loads above half load may be maintained constant as indicated by the lower curve D. Consequently, with differential firing of the furnaces, a substantially constant degree of superheat may be obtained at various loads, and by differential firing with the use of the by-pass, constant superheat may be maintained at various loads.

From the foregoing it will be perceived that in accordance with the invention, superheat control may be obtained readily in steam generators fired by a plurality of water cooled furnaces so arranged that the gases from the furnaces mix prior to entering the steam generating surface and prior to coming into contact with the super-

heater. By differentially firing the furnaces as hereinbefore described and by controlling the flow of gases through the by-pass, a constant or substantially constant degree of superheat may be obtained over a wide load range.

The particular arrangement and disposition of the steam generating and superheating sections of the forms of the invention selected for illustration may be varied without departing from the principles of the invention. For example, if desired, more than two furnaces may be employed. Means other than that disclosed may be utilized for controlling the rate of firing of the burners in the two furnaces. Such means may include automatic means responsive to the steam temperature to provide unequal firing in the desired direction and automatic means responsive to the pressure so as to maintain the firing rate at the desired value to produce the desired steam flow. More than one burner may, of course, be utilized in each furnace.

Since the invention is not limited to the forms selected for illustration, it will be understood that the invention is not to be limited excepting by the scope of the appended claims.

What is claimed is:

1. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from said mixing chamber, vapor generating surface in the path of the mixed gases flowing from said chamber and connected to said water walls in said furnaces, means forming a by-pass in the central portion of said gas passage, means for controlling the flow of gases through the by-pass, and superheating surface in said gas passage on both sides of said by-pass over which the gases from said mixing chamber flow in passing through said passage, the arrangement being such that the superheat temperature is controlled by unequally firing the furnaces to regulate the temperature of the gas mixture and by regulating the quantity of gases flowing through said by-pass.

2. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from said mixing chamber, vapor generating surface in the path of the mixed gases flowing from said chamber and connected to said water walls in said furnaces, means forming a by-pass in the central portion of said gas passage, means for controlling the flow of gases through the by-pass, superheating surface in said gas passage on both sides of said by-pass over which the gases from said mixing chamber flow in passing through said passage, and heat recovery surface in said passage in the path of the gases flowing from the superheating surface and from said by-pass.

3. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which

the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from said mixing chamber, means forming a by-pass in said gas passage, means for controlling the flow of gases through the by-pass, and superheating surface in said gas passage on both sides of said by-pass over which the gases from said mixing chamber flow in passing through said passage, the arrangement being such that the superheat temperature is controlled by unequally firing the furnaces to regulate the temperature of the gas mixture and by regulating the quantity of gases flowing through said by-pass.

4. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from said mixing chamber, vapor generating surface in the path of the mixed gases flowing from said chamber, means forming a by-pass in said gas passage, means for controlling the flow of gases through the by-pass, and superheating surface in said gas passage on both sides of said by-pass over which the gases from said mixing chamber flow in passing through said passage, the arrangement being such that the superheat temperature is controlled by unequally firing the furnaces to regulate the temperature of the gas mixture and by regulating the quantity of gases flowing through said by-pass.

5. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from said mixing chamber, means forming a by-pass in said gas passage, vapor generating surface in said by-pass, means for controlling the flow of gases through the by-pass, and superheating surface in the gas passage on both sides of said by-pass over which the gases from said mixing chamber flow in passing through the passage, the arrangement being such that the superheat temperature is controlled by unequally firing the furnaces to regulate the temperature of the gas mixture and by regulating the quantity of gases flowing through said by-pass.

6. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from said mixing chamber, means forming a by-pass in said gas passage, vapor generating surface in the path of mixed gases flowing from the chamber into the passage and by-pass, means for controlling the flow of gases through the by-pass, and superheating surface in the gas passage on both sides of said by-pass over which the gases from the mixing chamber flow in passing through the passage, the arrangement being such that the superheat temperature is controlled by unequally firing the

furnace to regulate the temperature of the gas mixture and by regulating the quantity of gases flowing through said by-pass.

7. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from said mixing chamber, means forming a by-pass for said passage and disposed to divide the passage into portions separated by the by-pass, vapor superheating surface in each portion of the gas passage in heat exchange relationship with gases flowing there-through from the mixing chamber, and means for controlling the flow of gases through the by-pass.

8. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from said mixing chamber, means forming a by-pass for said passage and disposed to divide the passage into portions separated by the by-pass, vapor superheating surface in each portion of the gas passage in heat exchange relationship with gases flowing therethrough from the mixing chamber, and means for controlling the flow of gases through the by-pass, the arrangement being such that the superheat temperature is controlled by unequally firing the furnaces to regulate the temperature of the gas mixture and by regulating the quantity of gases flowing through said by-pass.

9. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from the mixing chamber, means forming a by-pass for said passage and disposed to divide the passage into portions separated by the by-pass, vapor superheating surface in each portion of the gas passage in heat exchange relationship with gases flowing therethrough from the mixing chamber, means for controlling the flow of gases through the by-pass, and a heat recovery device in at least one of the portions of said passage in the path of the gases flowing from the superheating surface and from said by-pass.

10. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from said mixing chamber, means forming a by-pass for said passage and disposed to divide the passage into portions separated by the by-pass, vapor superheating surface in each portion of the gas passage in heat exchange relationship with gases flowing therethrough from the mixing

chamber, a heat recovery device in at least one portion of the passage in the path of the gases flowing from the superheating surface, the by-pass having gas outlets positioned adjacent the heat recovery surface so that gases discharged from the by-pass will flow over the heat recovery device, and means associated with the gas outlets for controlling the flow of gases through the by-pass.

11. Vapor generating apparatus comprising a setting, a plurality of furnaces in the setting arranged to operate in parallel, means for firing each furnace at various intensities, a water wall in each furnace, a mixing chamber into which the gases from each furnace flow and mix with the gases from another furnace, means forming a gas passage through which the mixed gases flow from said mixing chamber, means forming

a by-pass for said passage and disposed to divide the passage into two substantially parallel portions separated by the by-pass, the by-pass having gas outlets at opposite sides thereof and in communication with the separate portions of said gas passage, vapor superheating surface in each portion of the gas passage in heat exchange relationship with gases flowing therethrough from the mixing chamber, a heat recovery device in each of said portions of the gas passage in the path of gases flowing from the superheating surface, baffle means adjacent each gas outlet of said by-pass adapted to direct the gases from the by-pass over the heat recovery device, and means associated with the gas outlets for controlling the flow of gases through the by-pass.

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